THE OPERATION OF AN AMERICAN OR RAPID WATER FILTRATION PLANT FOR TWENTY YEARS AT ELMIRA, NEW YORK

By James M. Caird

Elmira, New York, has a population of about 45,000. It is located in the southwestern part of the State, on the Chemung River, a few miles from the Pennsylvania line. The greater part of the city's water supply is obtained from the Chemung River, which is formed by the uniting of the Tioga and Cohoctan Rivers, 19 miles from Elmira. The Chemung River is about 50 miles in length, and flows into the north branch of the Susquehanna River. The area drained above Elmira by the Chemung River and its tributaries is about 2050 square miles. The river is subject to severe floods, the water at times rising 18 feet.

On examining the polluting territory of the river for a distance of 50 miles above Elmira, there will be found over 75,000 people in cities and villages having direct sewage connection with the river. The water always contains a marked turbidity and color and carries heavy suspended matter.

At Elmira the water for filtration is taken from the river through cribs connected with a gallery, from which it flows by gravity to the pumps.

The pumping station is equipped with electric and steam driven turbine pumps, by which the water is lifted 118 feet for delivery and forced through a 20-inch main to the filtration plant, which is about 2 miles north of the pumping station. There is an auxiliary supply obtained from an impounding reservoir on the upper portion of Hoffman Creek, about ½ mile north of the filter plant. The water from this reservoir, when in use, flows by gravity to the filters. The impounding reservoir, was formed by the construction of a dam during 1870. It has a drainage area of about 4½ square miles, covers 38 acres and had a capacity of 113,000,000 gallons. A recent survey, however, shows that the capacity has been reduced to 90,000,000 gallons because of material washed in at the upper end.

This reduction of 20 per cent in capacity also reduces the time for natural sedimentation. The supply for this reservoir is derived from springs and the small Hoffman Creek.

At the time this reservoir was constructed, the timber and surface soil were removed from the district to be flooded. The water from this reservoir has given trouble at all seasons of the year, because of the disagreeable odor and taste produced by algae growths. To overcome these conditions the reservoir has been drained and cleaned several times, the last time being in 1889.

In 1904 copper sulphate was applied to the water in this reservoir for the first time, the result being so satisfactory that the treatment is applied whenever there are any signs of an excessive growth of algae. The copper sulphate applications have resulted in a great saving in the cost of operating the filters as well as in removing the cause of the disagreeable odors and taste. It was found that after the water had been treated the period between washing filters increased at least three hours, while the water required for washing filters was reduced from 2.3 to 1.9 per cent. As filtered water is used in washing the filters and has to be pumped, there is considerable saving in the operating cost. The bacterial content of the water, after the copper sulphate treatment, increases greatly.

Following an epidemic of typhoid fever in 1896, an American, rapid or mechanical filtration plant was installed in 1897, but owing to some litigation no coagulants were used until March, 1898. This plant is so located that the waters from the river or the storage reservoir are filtered before being delivered to consumers.

The original filter plant consisted of 18 subsidence gravity filters, each 13½ feet in outside diameter. In 1904 the capacity was increased by the addition of three units, so that the present plant consists of 21 units, each with an effective filtering surface of 113 square feet, or a total of 2373 square feet, which is about one-twentieth of an acre. The rated capacity of the plant is 7,000,000 gallons per day and under favorable conditions this rate has been greatly exceeded.

The process of filtration is as follows: The water to be filtered is first treated with a solution of sulphate of alumina, after which liquid chlorine is added. Originally the sulphate of alumina solution was pumped into the water before it entered the building, but this method proved to be unsatisfactory because of the variation of the steam pressure and the constant repairing of the chemical pump. In 1900

a gravity orifice feed was installed and proved very satisfactory. The sulphate of alumina was dissolved in two solution tanks having a capacity of 1700 gallons each; from the tanks the solution was pumped to the distributing tank which was placed at the top of the filter building; from this it flowed to the orifice box and then to the supply main. The excess amount of solution pumped returned to the storage tanks and kept them well mixed. The amount of solution applied to the water was governed by weir rings, and while this method produced good results in controlling the applied solution, the fact that it was necessary to pump the solution to the distributing box was a source of trouble and expense.

When the plant was enlarged, a chemical tower was constructed, thus obviating the necessity of pumping any of the sulphate of alumina or other solutions. The solutions are now applied through standard orifice feed boxes. The orifice box is so equipped with an electrical device that if the head over the orifice varies ½ inch, a bell calls the operator to adjust it.

The solution of sulphate of alumina is prepared by weight. It has been found that a strong solution will react more quickly and better than a weak one. The solution in the storage tanks is agitated by air, the power for operating the air pump being obtained from a water wheel which is located in the filtered water flume. Repeated tests show that the specific gravity of the solution is the same at the top and bottom of the dissolving tanks.

The sulphate of alumina is purchased under specifications, the requirements being as follows:

	per cent
Alumina (Al_2O_3) not less than	17.50
Acid (SO_3) not more than	37.50
Iron, total as (Fe_2O_3) not more than	0.40
Water (H_2O) not more than	47.00
Insoluble, not more than	0.25

It is understood that if the alumina (Al_2O_3) is over 17.5 per cent the acid (SO_3) may be increased in proportion. If the results of the analyses show the alumina to be below 17.5 per cent and above 17 per cent a deduction of 8 cents per 100 pounds is made. If the alumina is below 17 per cent and above 16.5 per cent a deduction of 15 cents per 100 pounds is made. For each 0.25 per cent or fraction thereof of iron (Fe_2O_3) above 0.40 per cent a deduction of 5 cents per 100 pounds is made. The sulphate of alumina shall not contain any free acid.

The maximum amount of sulphate of alumina used was 5 grains per gallon, while the minimum was 0.25 grain, and the average for the past twenty years is 1.29 grains per gallon, or about 185 pounds per million gallons of water.

The average amount of sulphate of alumina used during the 12 years before hypo-chlorite or liquid chlorine was used was 1.45 grains per gallon, while during the 8 years in which the sterilizing reagents have been used the average was 1.04 grains per gallon, showing a saving of 28.3 per cent.

The minimum amount of sulphate of alumina which will form any coagulation is about 0.33 grain per gallon; if less is used no coagulation is visible.

The large sulphate of alumina tanks are equipped with recording gauges, which indicate at all times the amount of chemical being applied.

At times, owing to a deficiency in the alkalinity of the unfiltered water, it has been necessary to add a small amount of lime or soda-ash. This is applied by gravity to the unfiltered water.

At times it has been necessary to add an alkali to the unfiltered water, although it contained an alkalinity of about 20 parts per million by both the methyl orange and erythrosine methods. This has been termed a "dead alkalinity" because it would not coagulate the sulphate of alumina.

When lime or soda-ash is used it is impossible to obtain a filtrate absolutely free from color.

Experiments have been made using sulphate of iron and lime as the coagulant, but this method failed to give results which were satisfactory.

Late in 1909 calcium hypo-chlorite was used. This solution was applied by gravity. In 1916 this method was replaced by liquid chlorine. The sterilizing solutions are added to the water before filtration and the results have been very satisfactory. While it may require a slight additional amount of gas over that required if it was added to the filtered water, it is possible to get a better mix and a longer period of contact by applying it to the unfiltered water and it also has the advantage that it prevents bacterial growths in the sand beds.

After treatment with sulphate of alumina and liquid chlorine the water passes to the subsidence basin under each filter, and is there retained from twenty to thirty minutes. In passing through the

subsidence basin about 30 per cent of the suspended matter is removed.

The water then passes to the top of the sand. After passing through the sand it is discharged into a flume which conducts it to the first filtered water reservoir.

The filter beds are about 48 inches in depth and have 9 inches of graded gravel over the strainers. The sand in the original filters came from Red Wing, Minnesota, but the sand for the new filters came from New Jersey. Sand to replace that lost during washing has been obtained from both of these places. The mechanical analyses of the sand show it to have an effective size of 0.56 mm., and a uniformity coefficient of 1.43.

In washing the filters about 7 gallons per square foot of surface per minute are used and at the same time the mechanical rakes are operated. The average amount of wash water during the past 18 years was 2.78 per cent of the water filtered. A filter is out of operation about six minutes per wash.

About ½ inch of sand is lost from the surface of the beds each year during washing. The lost sand is replaced every four or five years.

During the first few years after the plant was in operation it was customary to "sterilize" the sand beds every six months. This was done by placing about 200 pounds of soda-ash on the surface of the sand bed and then introducing live steam through the strainer system until the beds boiled for one hour. While this treatment cleaned the sand grains, it was found that it would be at least a week before the bacterial efficiency would be satisfactory, therefore the sterilization has not been used for the past fifteen years.

The strainers in the filters are known as "C-J", manufactured by the New York Continental Jewell Filtration Company. It has been found that it is necessary to repair some of the strainers about every seven years. This is done by removing the old rivets and gauze, and replacing the gauze and rivets, the men at the plant doing this work. There are 444 strainers in each filter, spaced on 6-inch centers. These strainers are screwed into lateral pipes, and the space is filled to the top of the strainers with concrete. Some of the lateral pipes are now being replaced after having been in continuous operation for over twenty years.

There are no automatic controllers on the effluent pipes from these filters. After washing the filters the effluent valve is partly opened and from time to time, as necessary, the operator opens the valve

until such time as the filters become clogged, when they are again washed.

The filter tanks, which are of 2½-inch cypress, show some decay in a few places and from time to time it has been necessary to replace some of the bands. The round bands seem to give better service than the flat bands.

Use is made of the water in the flume on its way to the first filtered water reservoir to operate a water wheel. This water wheel operates a pump which forces the filtered water to the laboratory and also operates the air pump which agitates the sulphate of alumina solution.

There are two filtered water reservoirs, both uncovered, and because of the constant motion of the water have given very little trouble from algae growths. The first reservoir has a capacity of about 3,500,000 gallons, and from it the water is pumped to a concrete reservoir of 5,000,000 gallons capacity. This concrete reservoir was installed in 1912. During the ensuing winters the ice pulled the concrete, in places, away from the reinforcing bars. In 1916 a cement gun was used to replace this concrete and since that time there has been no trouble due to the action of the ice.

In 1912, with a population of 38,000, the consumption was 6,275,000 gallons per day; during the year 1917, with a population of about 45,000, the consumption was 4,025,000 gallons per day. Since 1912 meters have been installed on nearly all services, which is the cause for the reduced consumption.

When this plant was first placed in operation bacterial examination of water was in its infancy. Previous to May, 1905, chemical and bacterial tests covering periods of two weeks were made four or five times each year. Since that time an extensive laboratory has been maintained and daily chemical and bacterial tests are made. Since these tests have been made it has been possible to keep the plant under control at all times and the results obtained show a better efficiency and more uniform results.

In determining the bacterial content of the water it has been found that gelatin media at 20°C. for forty-eight hours is most satisfactory. In determining the bacterial count all plates are made in duplicate and the average count reported. A large percentage of the filtered water plates are incubated for seventy-two hours and remain sterile at the end of this period. All sterile filtered water plates are recorded as containing 1 bacterium per cubic centimeter.

Table showing maximum, minimum and average bacteria per cubic centimeter (gelatin counts) unfiltered and filtered water supply of Elmira, New York

YEAR	UNFILTERED			FILTERED		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1898	9,300	675	2,280	325	15	76
1899	26,300	524	6,019	860	6	121
1900	838	316	547	60	4	17
1901	2,690	796	1,394	35	7	17
1902	28,500	795	10,905	1,816	12	402
1903	29,000	300	7,646	2,000	20	230
1904	18,300	190	1,761	900	2	50
1905	45,200	520	7,256	530	6	70*
1906	45,600	450	7,433	420	4	43
1907	150,000	370	9,278	470	1	52
1908	83,400	208	9,375	870	3	61
1909	121,800	290	9,904	985	1	87†
1910	142,000	160	9,234	320	1	18
1911	112,000	120	9,516	120	1	7
1912	328,000	380	18,137	190	1	16
1913	120,000	340	7,127	92	1	9
1914	84,000	210	8,973	86	1	8
1915	155,000	380	8,910	98	1	6
1916	113,000	350	10,594	60	1	5
1917	89,700	200	6,872	70	1	6
Average	85,231	379	7,660	515	4	65

* Daily.
† Hypochlorite first used.

During the past twenty years the average bacteria in the unfiltered water were 7660 per cubic centimeter while the filtered water contained 65 per cubic centimeter, a reduction of 99.15 per cent.

During the first twelve years when sulphate of alumina was used the average bacteria in the unfiltered water were 6153 per cubic centimeter and in the filtered water 102 per cubic centimeter, a reduction of 98.35 per cent.

During the six years when hypochlorite was used with the sulphate of alumina, the average bacteria in the unfiltered water were 10,313 per cubic centimeter, while the filtered water contained 11 per cubic centimeter, or a reduction of 99.90 per cent.

During the past two years when liquid chlorine was used with the sulphate of alumina, the average bacteria in the unfiltered water

were 8733 per cubic centimeter and in the filtered water 6 per cubic centimeter, a reduction of 99.93 per cent.

Since the plant was placed in operation 77.61 per cent of the 1 cubic centimeter samples of unfiltered water gave positive presumptive tests for B. coli communis; while 1.79 per cent of the samples of filtered water gave positive results, a reduction of 97.69 per cent.

Previous to the use of hypochlorite or liquid chlorine, 71.63 per cent of the unfiltered water samples and 9.87 per cent of the samples of filtered water contained B. coli communis, or a reduction of 86.22 per cent.

During the eight years since hypochlorite or liquid chlorine has been used, 82.91 per cent of the samples of unfiltered water and 0.53 per cent of the filtered water samples contained B. coli communis, or a reduction of 99.37 per cent. The use of calcium hypochlorite or liquid chlorine has increased the efficiency of this plant and reduced the cost of chemicals used in its operation.

In determining the turbidity, standards made from clay obtained from the watershed are used.

Table showing turbidity, in parts per million, of the unfiltered and filtered water supply of Elmira, New York

YEAR	UNFILTERED			FILTERED		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1901	100	35	60.0	0.0	0.0	0.00
1902	110	35	67.0	0.0	0.0	0.00
1903	700	7	56.0	3.0	0.0	0.60
1904	500	20	62.0	0.0	0.0	0.00
1905	650	6	34.0	0.0	0.0	0.00
1906	1,900	6	72.0	0.0	0.0	0.00
1907	1,000	3	35.0	0.0	0.0	0.00
1908	800	2	35.1	0.0	0.0	0.00
1909	200	2	18.7	0.0	0.0	0.00
1910	700	2	23.6	0.0	0.0	0.00
1911	800	8	38.1	0.0	0.0	0.00
1912	2,500	8	58.5	15.0	0.0	0.09
1913	600	8	54.4	0.0	0.0	0.00
1914	600	5	40.9	0.0	0.0	0.00
1915	6,000	8	99.7	0.0	0.0	0.00
1916	3,500	3	74.9	0.0	0.0	0.00
1917	2,500	3	82.1	0.0	0.0	0.00
Average..	1,356	9	53.7	1.1	0.0	0.04

The average turbidity of the unfiltered water was 53.7 and the filtered water 0.04 part per million, a reduction of 99.93 per cent.

During the winter months great care has to be exercised. It is at this season that the filters are most likely to become air bound, and water containing some turbidity likely to pass the filters. Although the filters have no loss-of-head guages, the operator can tell when the beds contain air, and after a short wash the filters are again placed in operation. Wash water applied for one minute is usually sufficient to expel the retained air.

In determining the color, the platinum-cobalt method is used.

Table showing color, in parts per million, unfiltered and filtered water, Elmira, New York

YEAR	UNFILTERED			FILTERED		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1901	40	20	28.1	0.0	0.0	0.00
1902	90	17	30.9	8.0	0.0	1.20
1903	45	11	23.0	5.0	0.0	0.60
1904	42	15	24.6	8.0	0.0	1.00
1905	40	10	18.5	0.0	0.0	0.00
1906	80	5	23.8	0.0	0.0	0.00
1907	50	0	18.4	0.0	0.0	0.00
1908	180	0	15.8	0.0	0.0	0.00
1909	45	2	12.1	0.0	0.0	0.00
1910	45	2	14.8	0.0	0.0	0.00
1911	50	6	19.2	0.0	0.0	0.00
1912	70	8	19.5	20.0	0.0	0.09
1913	45	8	16.6	0.0	0.0	0.00
1914	40	6	17.9	0.0	0.0	0.00
1915	60	3	16.9	0.0	0.0	0.00
1916	40	3	10.3	0.0	0.0	0.00
1917	60	6	17.9	0.0	0.0	0.00
Average..	60	7	19.3	2.4	0.0	0.17

During this time the average color of the unfiltered water was 19.3 and the filtered water 0.17 part per million, a reduction of 99.12 per cent. As previously stated, it is impossible to get a complete removal of the color when it is necessary to use lime or soda-ash.

Table showing alkalinity, in parts per million, unfiltered and filtered waters. Elmira, New York

YEAR	UNFILTERED			FILTERED		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1900	100	88	94.4	95	70	83.8
1901	165	41	101.1	145	31	83.5
1902	68	33	53.4	53	12	36.2
1903	86	28	60.2	78	18	45.7
1904	73	15	42.5	62	0	31.5
1905	86	30	65.3	74	17	53.0
1906	107	15	55.1	92	7	43.4
1907	92	14	51.5	81	4	40.0
1908	103	15	62.6	112	7	57.3
1909	109	12	64.5	106	0	56.6
1910	106	13	67.0	106	6	63.4
1911	90	15	54.3	87	12	49.8
1912	103	11	58.6	98	4	51.9
1913	95	15	58.0	89	7	51.7
1914	100	11	62.0	97	7	57.5
1915	88	13	49.6	85	9	44.2
1916	103	12	57.0	96	6	50.8
1917	93	12	50.5	88	10	41.2
Average..	98	22	61.5	91	13	52.0

During this period 9.5 parts per million of alkalinity were used, while the average amount of sulphate of alumina used was 1.29 grains per gallon. On this basis, 1 grain of sulphate of alumina required 7.35 parts per million of alkalinity for decomposition.

In 1908 it is seen that the maximum alkalinity of the filtered water was higher than in the unfiltered; this was one of the times when it was necessary to use lime, because of an inactive alkalinity.

The amount of sulphate of alumina required to remove a given color or turbidity depends to a large extent upon the temperature of the water; the higher the temperature, the less coagulant is required.

The plant has been inspected and tested frequently by the State Board of Health.

Under the law, physicians are required to report cases of typhoid fever to the Health Officer; a violation of this law is punishable by a fine. When a case is reported an official from the Health Department visits the case, making a sanitary inspection of the premises, and also taking notes regarding the source of the water and milk supplies and other data.

Table showing average color and turbidity in parts per million, unfiltered water, and sulphate of alumina used in grains per gallon, Elmira, New York

YEAR	COLOR	TURBIDITY	ALUM
1898			0.50
1899			1.28
1900			1.03
1901	28.1	60.0	1.36
1902	30.9	67.0	2.18
1903	23.0	56.0	1.89
1904	24.6	62.0	1.68
1905	18.5	34.0	1.67
1906	23.8	72.0	1.57
1907	18.4	35.0	1.55
1908	15.8	35.1	1.52
1909	12.1	18.7	1.30
1910	14.8	23.6	0.98
1911	19.2	38.1	0.95
1912	19.5	58.5	1.11
1913	16.6	54.4	1.08
1914	17.9	40.9	0.78
1915	16.9	99.7	0.97
1916	10.3	74.9	1.11
1917	17.9	82.1	1.33
Average..........	19.3	53.7	1.29

During 1896, before the installation of the filter plant, Elmira was visited by a typhoid fever epidemic. During the period from January 3 to September 1, there were 370 cases of typhoid fever, with 36 deaths, a mortality rate of about 10 per cent.

During the three years 1895–1897 before the filter plant was in operation, there were 624 cases, with 73 deaths, of typhoid fever, the death rate being 78.8 per 100,000 population.

During the twenty years 1898–1917 that the filter plant has been in operation there have been 1507 cases, with 207 deaths, of typhoid fever, the average death rate being 29.3 per 100,000 population, making a reduction of 62.8 per cent in the death rate.

The average typhoid fever death rate during the 12 years that only sulphate of alumina was used was 39.9 per 100,000 population; compared with the rate before filtration this is a reduction of 49.4 per cent in the rate.

During the eight years in which the sterilizing solutions have been used with the sulphate of alumina, the typhoid fever death rate has

been 13.5 per 100,000 population. Compared with the rate when sulphate of alumina was used, this is a reduction of 66.2 per cent, and if compared with the rate before filtration was introduced the reduction would be 82.9 per cent in the typhoid fever death rate.

The entire improvement in the typhoid fever death rate is not due to the improvement in the public water supply. When the filtration plant was placed in operation there were over 1200 private wells in use. These wells were very shallow and examinations showed that at least 65 per cent of them contained B. coli communis. As the water was cool in summer time and "grandfather" dug the well and lived to a ripe old age, it has been a long and hard educational fight to prove that the use of water from some of these wells was dangerous. At the present time, when a case of typhoid fever is reported and the patient used well water, the Board of Health examines the water from the well and if it is found polluted the well is closed. This action upon the part of the Health Department has gone a long way toward reducing the typhoid fever death rate. The Board of Health also follows up the various milk supplies and there has been an improvement in the quality of the milk.

In the summer the Board of Health runs a publicity campaign, warning the people of the danger of swimming in the river.

During the past twenty years there were 1507 cases of typhoid fever, 604 or 40.1 per cent of which claimed to have used nothing but city water; 430 or 28.5 per cent claimed to have used well water exclusively; 247 or 16.4 per cent claimed to have used mixed well and city water, while 226 or 14.9 per cent of the cases were imported.

During the past twenty years there were 207 deaths from typhoid fever; 75 or 36.2 per cent were users of city water; 65 or 31.4 per cent used well water; 28 or 13.5 per cent used mixed water, while 39 or 18.8 per cent were imported.

The total mortality rate was 13.7 per cent; city water rate, 12.4 per cent; well water 15.1 per cent; mixed waters 11.3 per cent; imported 17.2 per cent. The imported mortality rate is the highest. This no doubt is due to the fact that the patients are not brought in to the hospitals until they are in a very serious condition.

In June and July, 1908, there were 40 cases of typhoid with 4 deaths; 31 of these cases were on one milk route, and upon investigation an unrecognized or concealed case of typhoid fever was found on the producing farm.

In October, 1912, there were six cases of typhoid fever on one milk route; investigations failed to reveal the cause.

Table showing average bacteria per cubic centimeter of filtered water, percentage of samples showing B. coli communis and total typhoid fever death rate per 100,000 population, Elmira, New York

YEAR	BACTERIA	B. COLI	TYPHOID RATE
		per cent	
1898	76		51.8
1899	121		35.6
1900	17		47.7
1901	17		28.0
1902	402		44.9
1903	230	20.00	64.5
1904	50	13.33	53.3
1905	70	1.37	25.2
1906	43	18.71	39.2
1907	51	4.17	25.2
1908	61	6.04	30.8
1909	88	5.47	33.6
1910	18	0.00	26.4
1911	7	0.00	13.2
1912	16	1.81	15.9
1913	9	0.46	10.6
1914	8	0.00	10.6
1915	6	0.17	9.6
1916	5	0.35	9.6
1917	6	1.43	11.9
Average..........	65	4.88	29.3

In February, 1913, there were eight cases on one milk route, one case of typhoid fever being found on the producing farm.

In 1914 there were six cases in one house; all used the same well water.

In 1915, out of 34 cases in October, November and December, 15 were on one milk route. It was reported that a typhoid carrier was found on the producing farm.

Time is certainly required to educate the public as to the value of a pure milk and water supply.

While the Elmira plant does not embrace all of the latest improvements in the art of water purification, there are few plants that are producing better results.

Mr. Hiram F. Jones has been superintendent and resident chemist and bacteriologist since 1905. The plant is now owned by the City of Elmira and is operated by the Elmira Water Board.